Professor Revaz R. Dogonadze (1931-1985)

by Prof. Zurab D. Urushadze

Member of the Georgian National Academy of Sciences, Doctor (Dr.Hab) of the Physical and Mathematical Sciences, Professor Revaz (Rezo) R. Dogonadze outstanding scientist and public figure, one of the founders of Quantum Electrochemistry.

Revaz Dogonadze was born on November, 21, 1931, in Tbilisi (Republic of Georgia).
His father Roman I. Dogonadze (1905-1970) was a Professor of Economics.

- 1949-1955 - Student of the Moscow Physics-Engineering Institute.
- 1955-1958 - Post-Graduate Student of the Moscow Institute of Physical Chemistry.
- 1958-1978 - Research Scientist (1958-1962) and Senior Research Scientist (1962-1978) of the Theoretical Department of the Moscow Institute of Electrochemistry.
- 1961 - Revaz Dogonadze earned a doctorate (Ph.D.), in 1966 he was awarded the higher doctoral degree of Doctor of the Physical and Mathematical Sciences (Dr.Habil.).
- 1962-1973 - Associate Professor (1962-1969) and Professor (1969-1973) of the Moscow State University.
- 1968-1985 - Member of the International Society of Electrochemistry (ISE).
- 1978-1985 - Chairman of the Department of Electrochemical Physics and Member of the Board of the ISE.
- 1978-1985 - Founder and Head of the Department of Theoretical Investigations of the Tbilisdi Institute of Inorganic Chemistry and Electrochemistry.

- 1983 - Prof. Dogonadze was elected as a Member of the Georgian National Academy of Sciences.

- 1983-1985 - Head of the Department of Theoretical Physics of the Georgian Tech. University.

Z.D. Urushadze and R.R. Dogonadze (*right*) - Moscow, 1957

R.R. Dogonadze

Scientific interests of R. Dogonadze were closely connected with the theory of kinetic phenomena in condensed media. His pioneering works of 1958-59 have laid the foundations of the modern quantum-mechanical theory of elementary chemical processes in electrolyte solutions, later widely recognized and further developed by the studies of R.R. Dogonadze and his co-workers. Also, the development of the quantum theory of electrochemical kinetics is to a great degree due to the works of R.R. Dogonadze and his school. He developed a comprehensive quantum-mechanical theory of the elementary act of electrochemical reactions of electron and proton transfer at metal and semiconductor electrodes.

Revaz Dogonadze was the first scientist considering a chemical electron-transfer process as a quantum-mechanical transition between two distinct electronic states. This transition is induced by weak interactions between the molecular entities represented by the molecular states. One of the most important results of his study was recognition of the importance of nuclear tunneling. Chemical processes could proceed even at very low temperatures due to the nuclear tunneling mechanism. The electron transfer theory developed by Professor Dogonadze and based on quantum-mechanical transitions was published in 1959-1961.

The main scientific interests of Dogonadze were focused on condensed-phase reactions. His contribution to this field is difficult to overestimate. He had laid the basis for the quantum-mechanical theory of electron transfer in solutions. A large cycle of his studies, which were carried out in cooperation with his colleagues and pupils, embrace all the main aspects of this phenomenon. These include the theory of adiabatic and nonadiabatic electron transitions, the role of quantum and classic vibrational degrees of freedom, the role of high-frequency and low-frequency fluctuations of the solvent polarization, the electrode redox reactions, the processes accompanied by light absorption, the low temperature reactions, the bridge electron transfer reactions, and the electron transfer in biological macromolecules. Most of his results are fundamental and retain importance even now. In particular, he was the first to obtain, by a quantum-mechanical calculation, the expression for the electron transfer probability which was published in 1959.

$$W = \frac{1}{\hbar}|V|^2 \sqrt{\frac{\pi}{k_B T E_r}} \exp\left[-\frac{(E_r + \Delta F)^2}{4 E_r k_B T}\right]$$

Another fundamental result — the absence of an inversion region in the electrochemical reactions of electron transfer — was also obtained and explained in this cycle of studies. The criteria for adiabatic and nonadiabatic transfer mechanisms were found, and the method of multidimensional activated complex was developed for adiabatic reactions. Dogonadze and his colleagues also proposed the first quantum-mechanical model for the proton transfer, which took into account the role of the polar medium and a quantum nature of the proton behavior. In particular, the model allowed for the change in the intermolecular distance during the proton tunneling. The model had laid the basis for many later studies in this field. The theoretical studies on the bridge processes of the electron and proton transfer were far ahead of their time and were further developed only many years later.

Among the abundant results obtained by Dogonadze and his pupils, yet another one should be marked as pioneering. This concerns the polar-liquid model built as a set of effective oscillators. The model employs the strength of these oscillators expressed through dielectric properties of the liquid. Models of this kind are used now in theory of the electron transfer in dissipative environment. On the whole, the scientific work of Dogonadze has left its mark on theoretical chemical physics and will not loose its significance for further development of theory of the electrochemical and chemical kinetics.

Prof. Revaz Dogonadze lecturing

In the 1970's, a number of scientists of the Moscow Institute of Electrochemistry joined the group of Prof. Revaz Dogonadze to collaborate on the problems of an elementary act of chemical reactions and charge transfer in chemical processes. A number of scientists from western countries (USA, Denmark, Germany) came to Moscow to work with Prof. Dogonadze. Thus, a scientific school of Quantum Electrochemistry was formed around him. R.R. Dogonadze had an outstanding pedagogic talent. He has trained many pupils who worked actively and succesfully in quantum electrochemistry. For many years he delivered lectures on quantum mechanics, statistical physics and field theory at the Department of Mechanics and Mathematics of Moscow State University. He spared much attention to the upbringing and training of Georgian scientists and delivered new original lecture courses to the students of schools and colleges.

The scope of his scientific interests was extremely wide. He conducted a number of studies on the theory of low-velocity electrons in disordered systems, theory of solvated electrons and theory of photochemical processes in solutions. He made an impressive contribution to the theory of elementary biochemical processes. His work in this area has lead to the foundation of the theory of low-temperature charge transfer processes covering not only tunnel processes in biochemical and electrochemical systems, but also tunnel transport of atoms and defects in solids. These investigations were a significant contribution to the Theoretical Physics.

In 1977 Prof. Revaz Dogonadze was Editor of the Russian edition Prof. R. Bell's monograph "The Proton in Chemistry" (Publishing House "Mir", Moscow, 1977) and co-author of its appendix (E.D. German and R.R. Dogonadze. "The Quantum-Mechanical Theory of the Kinetics of Proton Transfer Reactions", pp. 350-376). Prof. Dogonadze was Co-Editor and co-author of a three-volume collective monograph "The Chemical Physics of Solvation" (Elsevier, Amsterdam, 1985-1986). Professor Dogonadze was the author of more than 190 scientific publications (among them 7 books). Under the guidance of Prof. R. Dogonadze were prepared 18 theses (13 Ph.D. and 5 Dr.Habil.).

Later Prof. Dogonadze became interested in the non-traditional methods of investigating interfaces, the electrodynamics of interfaces and the processes of vibrational relaxation.

R.R. Dogonadze chaired the Division of Electrochemical Physics of the International Society of Electrochemistry. He actively participated in all ISE activities and maintained close contacts with many scientists around the world. His last contribution to the international scientific cooperation was the conference on the interface boundary electrodynamics and quantum effects in adsorbed layers and films - "Telavi84" - that became a very significant event in the progress of electrochemical science.

On the evening of May 13, 1985, the distressing news reached the world's scientific community that had died Professor Revaz Dogonadze. His life was too short, but his incomplete 54 years were sufficient for him to have made a substantial contribution to science so that his name will always remain in the history of electrochemistry and chemical physics.

Founded by Prof. Revaz Dogonadze department of Theoretical Investigations of the Institute of Inorganic Chemistry and Electrochemistry of the Georgian Academy of Sciences is carrying his name since 1986.

International Conferences "The Kinetics of a Charge Transfer in the Homogeneous and Heterogeneous Systems" dedicated to Prof. Dogonadze's memory were organized in Tbilisi and Batumi in 1986 and 1989.

MAIN PUBLICATIONS OF PROFESSOR REVAZ R. DOGONADZE:

1. R.R. Dogonadze and A.M. Kuznetsov. "Contemporary State of the Theory of Electrode Processes". Publishing House of VINITI, Moscow, 1969 (in Russian).

2. R.R. Dogonadze and Z.D. Urushadze. "Semi-classical Method of Calculation of Rates of Chemical

Reactions Proceeding in Polar Liquids". J.Electroanal.Chem., 32 (1971), pp. 235-245.

3. M.V. Volkenshtein, R.R. Dogonadze, A.K. Madumarov, Z.D. Urushadze and Y.I. Kharkats. "Theory of Enzime Catalysis". Mol. Biol., Moscow, 6 (1972) pp. 431-439 (in Russian).

4. M.V. Volkenshtein, R.R. Dogonadze, A.K. Madumarov, Z.D. Urushadze and Y.I. Kharkats. "Electronic and Confirmational Interactions in Enzymic Catalysis". in: Konformatsionnye Izmenenia Biopolim. v Rastvorakh. Publishing House "Nauka", Moscow, 1973, pp. 153-157 (in Russian).

5. R.R. Dogonadze. "Theory of Chemical Reactions in Polar Liquids". Publishing House "Znanie", Moscow, 1973, 65 (in Russian).

6. R.R. Dogonadze and A.M. Kuznetsov. "Results of Science and Technology. Physical Chemistry. Kinetics.", Vol. 2: "Kinetics of Chemical Reactions in Polar Solvents". Publishing House of VINITI, Moscow, 1973, 209 (in Russian).

7. R.R. Dogonadze and A.M. Kuznetsov. "Theory of Charge Transfer Kinetics at Solid-Polar Liquid Interfaces". Prog. Surf. Sci., 6 (1975), pp. 1-42.

8. R.R. Dogonadze, A.M. Kuznetsov and J. Ulstrup. "Conformational Dynamics in Biological Electron and Atom Transfer Reactions". J. Theor. Biol., 69 (1977) pp. 239-263.

9. R.R. Dogonadze, A.A. Kornyshev, A.M. Kuznetsov and T.A. Marsagishvili. "Aspects of Electrodynamics of Electrochemical Systems". J. Phys. (Paris), Colloq., 1977, pp. 35-48.

10. R.R. Dogonadze and A.M. Kuznetsov. "Kinetics and Catalysis. Kinetics of Heterogeneous Chemical Reactions in Solutions". Publishing House of VINITI, Moscow, 1978 (in Russian).

11. R.R. Dogonadze. "Theory of Molecular Electrode Kinetics". in: Reactions of Molecules at Electrodes, N.S. Hush (Ed.), Interscience, London, 1971, pp. 135-227.

12. R.R. Dogonadze, A.M. Kuznetsov and T.A. Marsagishvili. "The Present State of the Theory of Charge Transfer Processes in Condensed Phase". J.Electrochem.Acta, 25 (1980) pp. 1-28.

13. R.R. Dogonadze and A.M. Kuznetsov. "Quantum Electrochemical Kinetics: Continuum Theory". in: Comprehensive Treatise of Electrochemistry, B.E. Conway, J.O'M. Bockris and E. Yeager (Eds.), Vol. 7, Plenum Press, New York, 1983, pp. 1-40.

14. R.R. Dogonadze, A.A. Kornyshev and J. Ulstrup. "Theoretical Approaches to Solvation".in: The Chemical Physics of Solvation, R.R. Dogonadze, E. Kalman, A.A. Kornyshev and J. Ulstrup (Eds.), Part A, Chapter 1, Elsevier, Amsterdam, 1985, pp. 3-35.

15. R.R. Dogonadze and T.A. Marsagishvili. "Methods of Quantum Field Theory in Electrodynamics of Solvation". in: The Chemical Physics of Solvation, R.R. Dogonadze, E. Kalman, A.A. Kornyshev and J. Ulstrup (Eds.), Part A, Chapter 2. Elsevier, Amsterdam, 1985, pp. 39-76.

PROMINENT PERSONS ABOUT PROFESSOR REVAZ R. DOGONADZE:

"I joined his group in Moscow. All through winter and spring, I worked hard, exploring new areas of science with him. In the summer he took my wife and me to Georgia, where we were received with the proverbial hospitality of his people... Prof. Dogonadze's place is assured in the future textbooks of Electrochemistry, and in the hearts of those who knew him." (Professor Wolfgang Schmickler, Germany).

"I first knew of Professor Dogonadze's accomplishments more than twenty-one years ago when, as a graduate student, I came to grips with his papers on the electron transfer theory. That was the Dogonadze (in print) of "Levich and Dogonadze" about whom so much had been talked and weitten about. Their work, and Marcus' independent contributions, was causing a well-deserved stir in the communities of both electrochemists and inorganic chemists. I felt rather small working in the shadow of these people." (Professor Piter Schmidt, USA, 1990).

J. Ulstrup and R.R. Dogonadze

"I have had the good fortune of being granted to work with Professor Dogonadze and enjoy his inspiration and friendship over a span of fourteen years. In crucial ways this has been a guideline and paved the way for my scientific undertakings. But like a cello which also gives off a whole spectrum of overtones when struck, so are the memories of Rezo's colleagues and students enriched also by numerous stronger and weaker overtones which relate to Rezo's impact on many facets of their lives. We recall Rezo as the brilliant scientist, as the scintillating lecturer, and as the careful tutor." (Professor Jens Ulstrup, Denmark).

"It was with a sense of shok that we learned about the untimely death of our colleague Rezo Dogonadze. One of us (R.A.M.) met Rezo only infrequently - and not since 1971 - but his cheerfulness and the depth of his insight so evident in his work will always be remembered. Nowadays, in the electron transfer field to which Rezo devoted so much of his interest, there have been an increasing number of studies on the possible extent of solvent dynamics effects on some electron transfer rates. The work has been both experimental and theoretical. Although Rezo's bent was often towards the quantum side of the electron transfer, his interest in relaxation was evident, and we could well have imagined his plunging into this

new area." (Prof. R.A. Marcus, USA and Prof. H. Sumi, Japan, 1986).

"Fundamental concepts for a theoretical description of electrode reactions were developed by Butler and Volmer, and Gurney and Marcus. Our understanding, however, is based mostly on the subsequent quantum-mechanical approach to electrochemistry which was developed by Rezo Dogonadze. That was clearly demonstrated by the Conference in Telavi which was organized by Rezo Dogonadze himself just before his sudden death. Electrochemists mourn the death of this excellent scientist and good friend." (Prof. J.W. Schultze and Dr. L. Elfenthal, Germany, 1985).

"Professor R.R. Dogonadze provided electrochemists with theoretical tools and insight, and encouraged also experimentalists to unravel fundamental dynamics in electrochemical and photoelectrochemical systems." (Dr. K. Bitterling and Dr. F. Willig, Germany).

L.I. Krishtalik and R.R. Dogonadze *(right)*

"Prof. R.R. Dogonadze's fundamental contribution to chemistry lies in the creation of a consistent quantum-mechanical theory of charge transfer reaction in condensed media. One of the basic concepts of the theory is the idea of quantum and classical degrees of freedom and their appreciably different behaviour during the elementary act. The conclusion about the prevalence of a purely quantum sub-barrier proton transfer without preliminary stretching of its covalent bond was absolutely unexpected for the majority of chemists." (Prof. L.I. Krishtalik, Russia).

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HOME